INVASION OF VIRGIN SOIL IN THE TROPICS[1]

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(WITH TWO FIGURES)

This note is concerned with the revegetation of a tropical valley which was denuded of plants by a flood and later filled with detritus from a landslide. Acknowledgments are due to Messrs. H. A. GLEASON, WILLIAM HARRIS, M. A. HOWE, E. P. KILLIP, W. R. MAXON, and PERCY WILSON for the identification of plants collected in the Cascade Valley; to E. P. KILLIP and WILLIAM SEIFRIZ for taking photographs of the valley; and to JONAS WALKER, a Jamaican collector, for gathering plants growing in the valley in December.

The Blue Mountain region of Jamaica was subjected, in November 1909, to several days of nearly continuous torrential rains, such as apparently occur there only once or twice in a century. On November 8, 1909, there was a rainfall of 18.3 inches in 24 hours at the Cinchona Station, and this downpour continued into the next day, until 27 inches had fallen. The rainfall was undoubtedly heavier still on the higher peaks of the Blue Mountains which drain into the valley under discussion.

The floods arising from these tremendous rains caused striking changes in the topography, and in the plant covering of many considerable areas on both the north and the south sides of the Blue Mountains. In the first place, many small streams rose two or three meters above the normal level, and scoured their rocky banks clean of vegetation, aside from larger trees, for many meters on either side. In the second place, there were landslides from the wooded mountain sides, and especially from the cultivated coffee fields, which completely carried away soil and vegetation from scores of acres on the south side of the mountains. These landslides not only left great scars, showing the bare rock on the formerly tree-covered mountain sides and in the coffee fields

[1] Botanical contribution from the Johns Hopkins University, no. 70.

lower down, but they also filled in whole valley bottoms with the rock and gravel washed down from above. The amount of water and of débris carried with it was sufficient to wash away or bury out of sight most of a large and substantially constructed stone and concrete "coffee works" near the Cascade River.

The effect of the flood and landslides on the topography and vegetation of the valley of the Cascade River, a normally small mountain stream, located about three miles east of the Cinchona Botanical Station, was briefly described in a note published in 1910.[2] At that time, which was but six months after the flood, the floor of this valley was still a barren waste, covered with pebbles and broken rock fragments of all sizes, ranging from that of a pea up to bowlders a meter in diameter. The only plants evident at this time were a few widely scattered seedlings of *Bocconia frutescens* and still fewer seedlings of half a dozen other dicotyledons, such as grow on the hills beside the valley. The largest of these plants were only 2 or 3 dm. high. In other words, the valley bottom, which in 1903 and 1906 I had seen covered with a forest consisting of large trees together with dozens of types of shrubs and herbs, was in 1910 an all but absolute desert. The forest had been completely washed away or buried, and there was left a truly virgin soil, with no trace of humus, which bore but the barest sprinkling of young seedlings.

After studying the conditions in this and other valleys in 1910, and taking into account the abundant rainfall and frostless climate of the region, it was concluded that the floor of the Cascade Valley would probably be recovered with a dense vegetation, although perhaps not with a fully developed forest, in a score or two of years. It was realized, of course, that many of the forest plants, being dependent on an abundant humus, would not find satisfactory conditions there for many years, because of the slowness with which this type of soil is developed.

On a trip to Jamaica, in July 1919, I again visited the Cascade Valley, and expected to find that, during the nine years that had elapsed, the few plants that were starting on the newly deposited gravel in 1910 had multiplied greatly, and that many new species

[2] Jour. New York Bot. Gard. 11:273. 1910.

would be establishing themselves among those first invaders. Many of the possible invaders of the valley, found on the neighboring hills, have a long growing season. There are some species that grow actively from February to September, while still others grow practically throughout the whole year.[3] Because of this long growing season and the possibility of some humus washing down from the surrounding hills, it was assumed that by 1919 the soil of the valley floor would be well hidden by a plant covering.

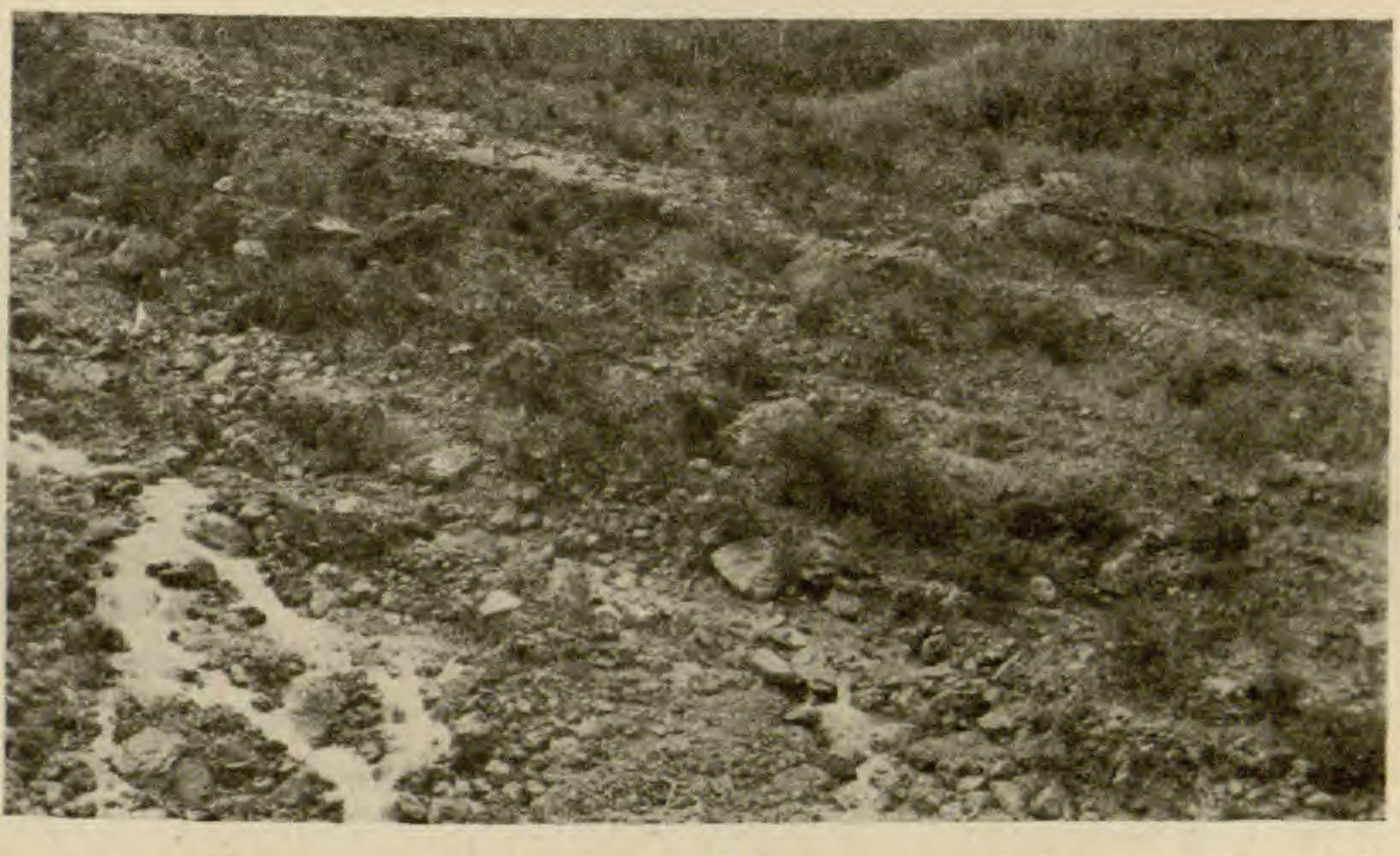

FIG. 1.—Looking east across Cascade Valley, showing sparse vegetation, which sparseness would be still more evident if viewed from above.

My surprise was great, therefore, when I found hardly more than a tenth of the gravelly bottom of the Cascade Valley hidden by plant foliage. The soil between these leafy plants, it is true, was not absolutely bare. There were a few very small patches of lichens and mosses. There was also a chroococcaceous alga, *Gloeocapsa magma*, which formed smooth encrustations often several square decimeters in extent on the pebbles and bowlders. This alga is present not only near the streams but across the whole floor of the valley. When dry *Gloeocapsa* has a rather dirty or chocolate brown color, but when wet it becomes a glistening velvety layer of a dark maroon color. It evidently thrives on these bare

[3] SHREVE, F., Publication no. 199, Carnegie Inst. Wash. pp. 51–52. 1914.

rocks, although they may often be exposed to a scorching sun for many hours daily and be without rain for days or even several weeks together. There is a copious dew in the valley each clear night, however, while on cloudy nights the fog probably condenses on the rocks and plants of its floor. It is likely that *Gloeocapsa* may thus be able to carry on photosynthesis and growth for some hours each day, even without rain.

The bareness of the valley bottom recalled that of the more barren of the stony deserts of Arizona as they appear in early summer. The general aspect of this valley differed from that of these deserts in the absence of cacti and of all larger woody plants. No plants of this valley exceeded a meter or two in height except where, at the very edges of the valley, considerable top soil, that had washed down from the hillsides, afforded better conditions for plant growth. Here several species of shrubs grew to two or three meters in height, and in wetter soil considerable stands of *Arundo* sp. had established themselves (fig. 1, *x*). The shrubs and cane together made a conspicuous verdant border to the generally desert-like valley floor.

When the floor of the valley, especially the portion along the trail from the junction of the Cascade and Green rivers to Farm Hill Coffee Works, was more carefully examined, the scattered vegetation was found to include the following plants:

ALGAE

Gloeocapsa magma (Breb.) Kütz.

PTERIDOPHYTA

Dryopteris oligophylla Maxon
Blechnum occidentale L.
Gymnogramme tartarea (Sw.) Desv.
Trismeria trifoliata (L.) Diels
Pityrogramma calomelaeana (L.) Link
Pteris longifolia L.
Aneimia adiantifolia (L.) Sw.

DICOTYLEDONEAE

Piper sp.? (shrub or tree)
Pilea microphylla L. (Liebm.) (annual to perennial)
Iresine celosioides L. (half shrubby)
Begonia acuminata Dryand. (half shrubby)
Asclepias curassavica L. (perennial herb)
Asclepias nivea L. (perennial herb)
Philibertella clausa (Jacq.) Vail (shrubby vine)
Duranta plumieri Jacq.(shrub 2-3 meters)
Verbena bonariensis L. (perennial herb)
Solanum torvum Sw. (half sh rubby)
Maurandia scandens A. Gr. (shrubby vine)

MONOCOTYLEDONEAE
Arundo (saccharoides Gr. ?)

Ageratum conoyzoides L. (annual)
Ageratum houstonianum Mill. (annual)
Vernonia acuminata Less. (half shrubby)
Vernonia permollis Gleason (half shrubby)
Mikania scandens L. (Wild.) (shrubby vine)
Eupatorium triste DC. (half shrubby)
Baccharis scoparia Sw. (shrubby)
Pluchea odorata L. (Cass.) (half shrubby)
Bidens incisa Ker. (annual)
Senecio discolor (Sw.) DC. (shrubby)

There were thus seven species of ferns, of which *Dryopteris oligophylla*, *Blechnum occidentale*, and *Aneimia adiantifolia* were rare, less than a score of each being seen where we crossed the valley. *Pityrogramma calomelaena* and *Gymnogramme tartarica* were more frequent; while *Trismeria trifoliata* was represented by dozens of specimens in the moister soil, and of *Pteris longifolia* there were still more numerous clumps in the drier spots along the trail across the valley. From the size of many of the fern plants seen it seems clear that they have been established for some time. In the cases of *Gymnogramme* and *Trismeria*, where fronds a meter high were seen, it was hard to believe that such plants could have arisen from a prothallus in nine years. Yet they must have done so unless it is assumed that old rhizomes have persisted in the soil to push up through the gravel, or that pieces of rhizomes have been washed down by the flood of 1909 or subsequent lesser ones. The first supposition seems negatived by the fact that no ferns were seen in 1910, six months after the flood, and also by the fact that each clump of a fern consists of but one or a few branches and leaf clusters. This latter feature tends to confirm the impression gained from the character of the soil, namely, that these ferns have started *in situ* from prothallia.

All the seed plants found in the valley, except *Arundo* along the stream at the foot of the cliff, were dicotyledons. By far the most important of these was the composite *Vernonia permollis*. Scores of clumps of this, from quite young plants up to those 2 m. high, were found scattered across the valley. They grew beside the larger rocks and often also formed rather definite rows along

the small dry gullies, which during the rainy season drain the raised middle of the valley floor that lies between the main stream on the west and the branch stream that comes in from the east. This ironweed is the most prominent plant of the valley, not only because of its abundance but also from its size. It is this plant, for example, that forms the major component of the clumps shown in fig. 1. The three more prominent plants after *Vernonia permollis* are *Bocconia frutescens* (already grown to 2 or 3 m. in height), *Solanum torvum Sw.* (often 2 m. high), and *Vernonia acuminata*

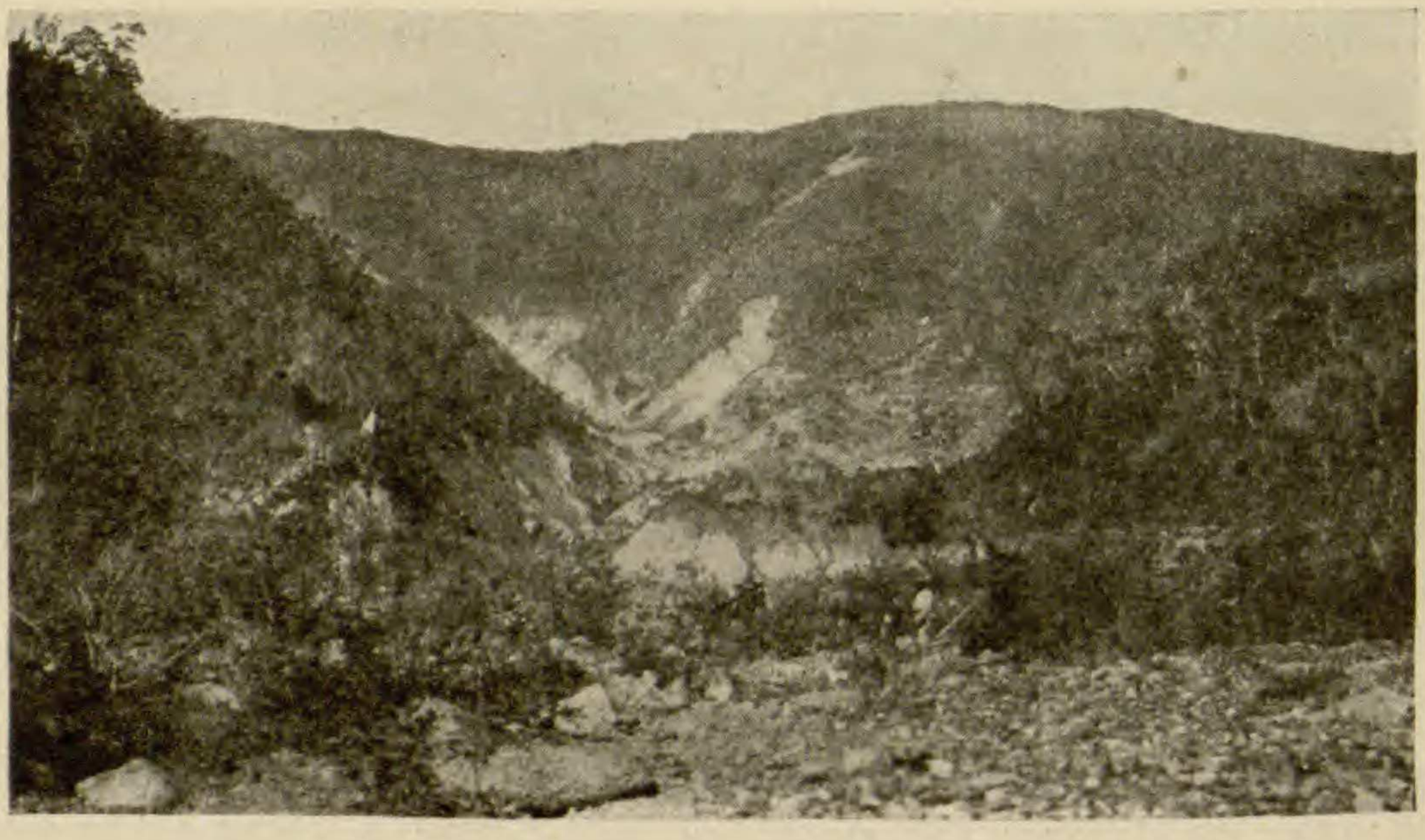

FIG. 2.—Looking north over upper Cascade Valley, showing scars left on south side of Blue Mountains by landslides.

(about 2 m). These larger plants are sometimes mingled with the *Vernonia permollis*, although much fewer than the latter, but may also be scattered sparingly by themselves over the valley floor.

Of the less prominent seed plants of the valley, some fifteen species were found. These, with their relative abundance, are: *Piper* sp.? (two or three young plants), *Pilea microphylla* L. (Liebm.) (rather frequent), *Iresine celosioides* L. (sparse), *Begonia acuminata* (very few), *Asclepias curassavica* L. and *A. nivea* L. (both infrequent), *Philibertella clausa* (Jacq.) Vail. (a dozen plants seen), *Duranta plumieri* Jacq. (half a dozen plants), *Verbena bonariensis* L. (few), *Solanum torvum* Sw., *Maurandia scandens* A. Gr. (occa-

sional at edges of valley), *Ageratum conyzoides* L. and *A. houstonianum* Mill. (rare), *Mikania scandens* L. (Wild.) (infrequent), *Eupatorium triste* DC. (few), *Baccharis scoparia* sp. (a dozen or so), *Pluchea adorata* L. (Cass.) (not infrequent), and *Bidens incisa* Ker. (frequent). All of these plants, with the possible exceptions of the *Pilea* and *Bidens*, were far less abundant than any of the four species mentioned in the preceding paragraph. Most of these fifteen plants are also smaller species, which likewise makes them less conspicuous in the vegetation of the valley. The *Duranta*, *Solanum*, and *Baccharis* are now as large as the species of *Vernonia*, but not as numerous. The climbing forms *Philibertella*, *Maurandia*, and *Mikania* of course are rather long, having already reached and spread over the tops of the largest plants near them. Many individuals of these fifteen species, as for example those growing in unusually dry situations, were dwarfed, and thus showed by their stunted form that they were not finding optimum conditions in the sterile soil and dry exposed situations afforded by the gravelly floor of the valley.

It is to be noted that, contrary to the accepted rule for invaders of new soil areas, as stated by WARMING,[4] the plants now established in the Cascade Valley are not mostly annuals or biennials. Instead they are chiefly perennials, and in fact shrubby or half-shrubby ones. Although this is true, it is to be noted also that not one arborescent form has yet been found, unless some of the young plants of *Piper* seen should prove to belong to one of the more tree-like species of this usually shrublike genus.

In this area of virgin soil there are present right through the year all of the climatic factors, such as moisture, heat, and light, that are needed for the production of a rich vegetation. This is evident from the dense forest that has developed in the adjoining valleys and even on the hills immediately overhanging the Cascade Valley itself. It was for these reasons that the writer was rather surprised, on revisiting this valley in 1919, at the slowness with which it is being recovered with vegetation. He was surprised not only at the relatively small number of new individuals, but especially at the very small number of species that had established themselves in the

[4] Oecology of plants. p. 356. 1909.

decade. It was anticipated in 1910 that certain plants which require abundant humus would not be able to settle at once on its bowlders and gravel, nor could epiphytes soon find the necessary trees to perch in. That the many mosses, ferns, and seed plants that grow all about the valley, not only in similar gravelly and stony soil along the trails, but even in the crevices of every rugged cliff and crag of the neighboring hills, should prove incapable of promptly and completely colonizing this valley was quite unexpected.

The decisive causes responsible for this slowness of revegetation have not been determined. It may be remarked in the first place that browsing by animals is a negligible factor in the development of the vegetation, since such animals are not allowed to run free in this region. Furthermore, it does not seem probable that the chemical nature of the rock can be the prime cause of this phenomenon. It is conceivable that at a later stage the soil formed by disintegration of the rock, which is an epidosite (or epidote gneiss), may determine the types of micro-organisms living in the soil and so the kinds of humus produced. The fact that a rather varied series of some thirty species of plants have been able to establish themselves in this valley shows that the soil, which is probably of fairly uniform chemical character throughout, is not especially unfavorable to plants. The distribution of the plants now growing in the valley seems rather to be related to the physical character of the soil. Plants are found growing where finer soil particles have accumulated. Probably the most important hindrance to the increase of the vegetation is instability of the soil, which, in most areas of this rather steeply sloping valley, is being constantly changed, by erosion at some points and by deposit at others.

It seems clear that in the future development of the plant covering of this valley the existing vegetation after a time will establish more fixed conditions in areas now occupied. This will give the mycorhizal fungi and soil bacteria, which cannot thrive in this sterile gravel, a sufficient amount of vegetable matter on which to feed. There will then probably be a decided acceleration both in the spread of the plant species now present, and in the introduction of new species. The writer hopes, during the coming decade, to be able to study further and to report on the progress of the revegetation of this valley.

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